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GEOLOGY OF THE JOHNSTON GRADE AREA
SAN BERNARDINO COUNTY
CALIFORNIA

By ROBERT B. GUILLOU

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GEOLOGY OF THE JOHNSTON GRADE AREA SAN BERNARDINO COUNTY, CALIFORNIA *

BY ROBERT B. GUILLOU

OUTLINE OF REPORT

Page
Abstract 3
Introduction 3
Descriptive geology 5
  Baldwin gneiss 6
  Saragossa quartzite 7
  Chicopee formation 7
  Furnace limestone 10
  Cactus quartz monzonite 12
  Quaternary sediments 13
    Fanglomerate 13
    Alluvium 13
Structural geology 13
  Folding 14
  Pre-Tertiary faulting 14
    High-angle faults 14
    Low-angle faults 14
  Late Cenozoic faulting 14
    High-angle faults 14
Geomorphology 15
Economic geology 16
  Metallic minerals 16
  Non-metallic minerals 16
Geologic history 16
References 18

Illustrations

Plate 1. Geologic map and sections of the Johnston Grade area, San Bernardino Mountains, San Bernardino County, California In pocket
Figure 1. Index map showing location of Johnston Grade area 4
2. Generalized stratigraphic column, Johnston Grade area 5
3. Photo showing Cushenbury Canyon. Furnace limestone on both sides 6
4. Photo showing augen gneiss facies of Baldwin gneiss 6
5. Photo showing Saragossa quartzite west of Baldwin Lake 7
6. Photomicrograph of gray quartzite in lime-silicate member of Chicopee formation 8
7. Photomicrograph of gray quartzite in lime-silicate member of Chicopee formation 8
8. Photo showing overturned cross-lamination in Chicopee formation 8
9. Photo showing blastosephite from Chicopee formation 8
10. Photo showing blastosephite from Chicopee formation 9
11. Photomicrograph of blastosephite from Chicopee formation 9
12. Photomicrograph of blastosephite from Chicopee formation 9
13. Photo showing contact-metamorphosed marble on Blackhawk Mountain 11
14. Photo showing typical exposure of Cactus quartz monzonite 12
15. Photomicrograph of Cactus quartz monzonite 13
16. Photomicrograph of Cactus quartz monzonite 13
17. Photo showing fault in Furnace limestone 14
18. Photo showing Helendale fault zone 15
19. Photo showing Helendale fault zone 15

ABSTRACT

The Johnston Grade area, lying on the north-central flank of the San Bernardino Mountains, San Bernardino County, includes 15 square miles of Lucerne Valley quadrangle in a strip extending from Baldwin Lake to Cushenbury Canyon.

The oldest rocks in the area are mapped as Baldwin gneiss (pre-Cambrian ?), a complex of gneiss and augen gneiss, and two pre Carboniferous granitic intrusives. Two predominantly quartzite pre-Carboniferous formations are mapped: the Saragossa quartzite, white-to-buff massive quartzite exposed in a thrust plate; and the Chicopee formation comprising lime-silicates, cross-laminated gray quartzite, and white quartzite. Overlying the quartzites are gray and white marbles of the Furnace limestone (Carboniferous). The foregoing are intruded by the Cactus quartz monzonite (Jura-Cretaceous). Quaternary deposits include fanglomerate and alluvium.

In the western part of the area overturning of the Paleozoic sediments, thrust faulting, and high-angle faulting took place prior to the intrusion of the Cactus granitic rocks. Late Cenozoic reverse faulting occurred on Blackhawk Mountain. The Helendale vertical fault cuts through the center of the area and offsets the fanglomerate.

INTRODUCTION

The Johnston Grade area lies on the north-central flank of the San Bernardino Mountains in the Lucerne Valley quadrangle, San Bernardino County, in southern California. It includes a strip 3 miles wide in the southwest quarter of the Lucerne Valley quadrangle, extending northwest from a point three-quarters of a mile north of Smarts Ranch to Monarch Flat, a mile and a half south of Cushenbury Springs. State Highway 18, a paved road which almost completely traverses the area from north to south, gives easy access from Victorville and Lucerne Valley, 47 and 15 miles to the north, and from Big Bear Lake, 10 miles to the west. A partly graded dirt road leads from the southern portion of the area to the Rose mine, Rattlesnake Canyon, and Twenty-nine Palms. Highway 18 is the only road kept free of snow during the winter.

Three principal geographic divisions of the area are recognized: Cushenbury Canyon, Cactus Flat and its prolongation to the south, and Baldwin Lake and the ridge east of it. Cushenbury Canyon is a short, steep-sided gorge which issues from the mountains into Lucerne Valley. Its walls rise more than 1500 feet above the stream bed which has an altitude of from 4500 to 5500 feet above sea level. South of Cushenbury Canyon is a moderately rolling area extending from Cactus Flat southeast to Smarts Ranch. This area, with an elevation of from 5700 to 6000 feet, is drained by Arrastre and Grapevine Creeks. The ridge east of Baldwin Lake rises 500 to 800 feet above the Cactus Flat-Smarts Ranch division.

The lower part of Cushenbury Canyon experiences the hot, dry summer and cool, semi-arid winter climate of the Mojave Desert. The higher portions of the area are characterized by the warm summers and cold winters of the high mountain areas of southern California. The average annual rainfall varies from about 30 inches at Baldwin Lake to less than 5 inches on the desert. Pinyon-juniper woodland is the dominant vegetation in the Johnston Grade area. Although the best stands are found from Cactus Flat up to Baldwin Lake, scattered trees are in

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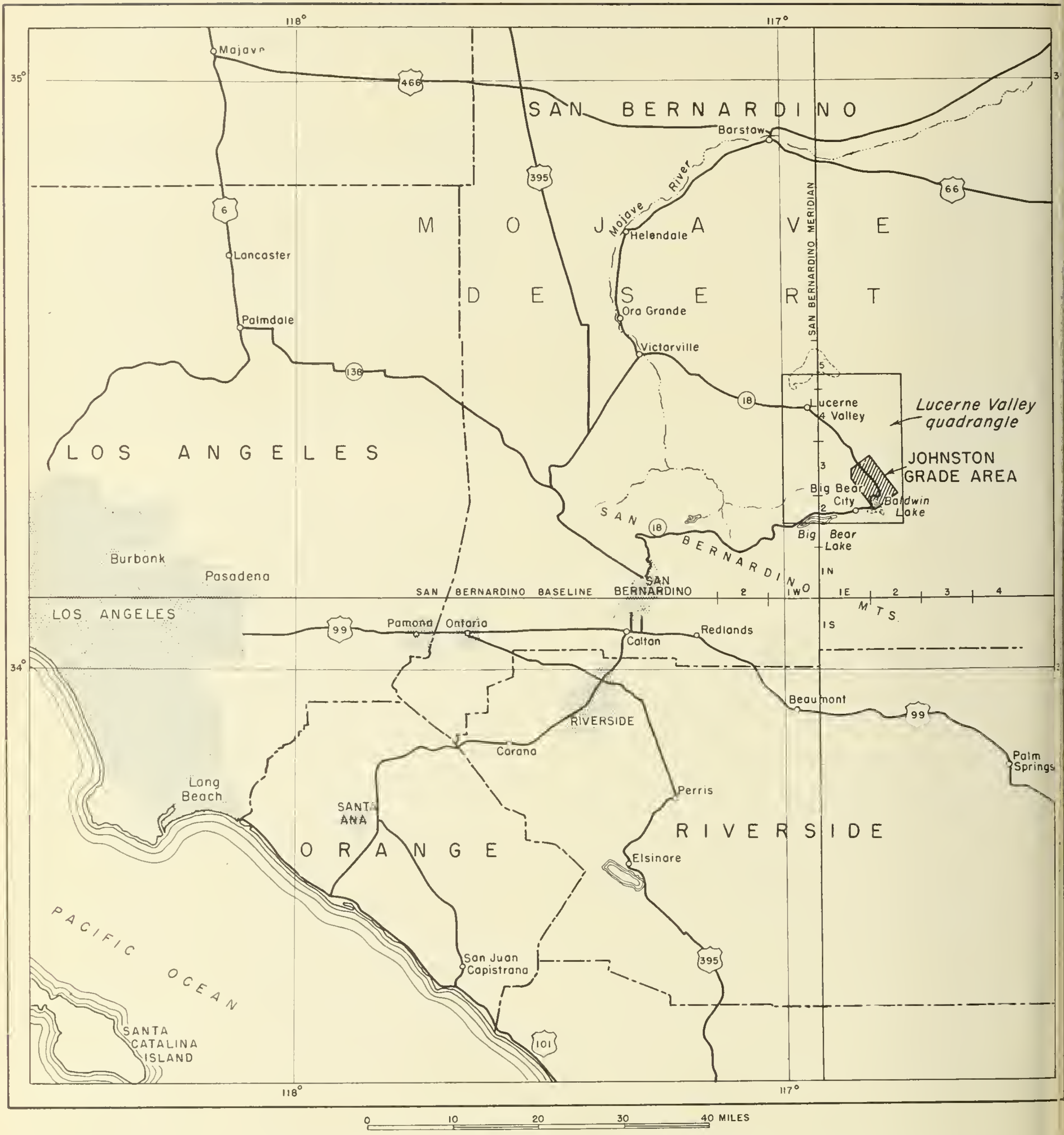

FIGURE 1. Index map showing location of Johnston Grade area.

Cushenbury Canyon, but they give way to the sagebrush, saltbrush, creosote bush, and other shrubs of the desert zone. Associated with the pinyon and juniper are scrub oak, mountain mahogany, common sagebrush, and Joshua tree. Several relatively pure stands of Joshua tree are on the fanglomerates and alluvium at Cactus Flat. Cholla cactus is also common in these areas. In Chicopee Canyon, at an elevation of 6500 to 7500 feet, yellow pine is found with associated maul oak, incense cedar, and white fir.

The only published geological investigation of this area was made by F. E. Vaughn (1922). The formation names proposed by Vaughn are used in this report, with modifications, but Vaughn's stratigraphic sequence is completely changed.

The geology of Blackhawk Canyon, to the east of Cushenbury Canyon, was described by Woodford and Harris in 1928. The thrust faults described in that paper have been included in the accompanying cross-sections.

This report is based on field work done during the summer and fall of 1950. A few additional days spent in the area in the spring of 1951 brought the total field days to 75. Eighteen by eighteen inch enlargements (approximately 1:12,000 scale) of aerial photos taken in 1945 and 1946 for the U. S. Geological Survey were used as field maps. An enlargement of a portion of the Lucerne Valley quadrangle (USGS, 1948) was used as a base map. Approximately 15 square miles were mapped.

Acknowledgments. The cooperation of Leo Slattery, District Ranger, U. S. Forest Service, and Fred Tomlinson, who allowed the author access to the San Bernardino National Forest and Burnt Flat areas, is gratefully acknowledged. The author is especially indebted to the Ralph W. Millers for their hospitality and interest shown during days spent in the field. Cordell Durrell, W. C. Putnam and D. I. Axelrod, members of the staff of the Geology Department of the University of California at Los Angeles supervised the investigation and offered constructive criticisms during the writing of the report.

DESCRIPTIVE GEOLOGY

The rocks of the Johnston Grade area are primarily pre-Tertiary in age. The following formations are recognized: Baldwin gneiss, believed to be pre-Cambrian; massive, fractured quartzites representing the Saragossa quartzite, of probable pre-Carboniferous age; lime-silicate rocks, cross-laminated quartzites, and white quartzites of the Chicopee formation, Mississippian or Devonian; marbles of the Furnace limestone, part of which at least belong to the Pennsylvanian; Cactus quartz monzonite and related intrusives, regarded as Jura-Cretaceous; and fanglomerates and alluvium of Quaternary age.

The Baldwin gneiss is a complex composed of gneiss, augen gneiss, and two pre-Mississippian granitic intrusives. The Saragossa quartzite is present in a thrust plate which overrides the Baldwin gneiss and portions of the Chicopee formation. Neither the age of the Saragossa formation nor the origin of the thrust plate is known. The Saragossa is presumed to be younger than the gneiss and older than the Chicopee formation. The pure white, the micaceous cross-laminated, and the limy sandstone beds of the Chicopee formation were deposited on the eroded surface of the Baldwin gneiss. Conformably deposited on the Chicopee formation were the shaly limestones and the limestones of the Furnace limestone. Metamorphism followed causing the conversion of the sandstones and limestones to quartzite and marble. During the Jura-Cretaceous, the Cactus quartz monzonite and its earlier facies, aplite and quartzite diorite, intruded the older rocks of the area in several places. Fanglomerate and alluvium are the only post-intrusive rocks in the area.

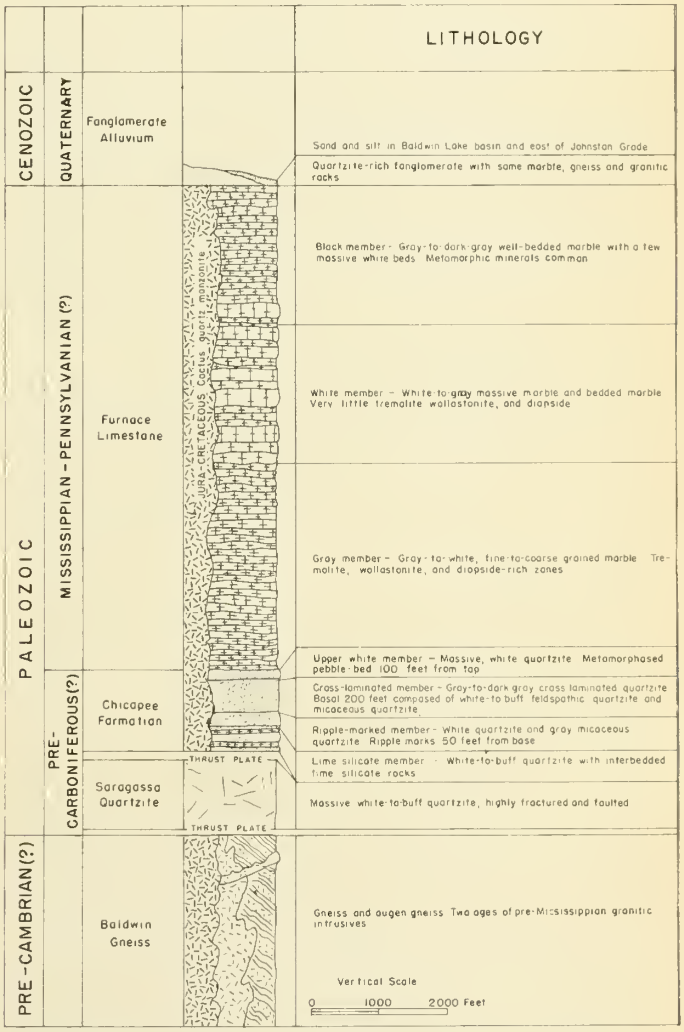
LITHOLOGY
CENOZOIC
QUATERNARY
Fanglomerate Alluvium
Sand and silt in Baldwin Lake basin and east of Johnston Grade
Quartzite-rich fanglomerate with some marble, gneiss and granitic rocks
PALEOZOIC
MISSISSIPPIAN-PENNSYLVANIAN (?)
Furnace Limestone
JURA-CRETACEOUS Cactus quartz monzonite
Black member - Gray-to-dark-gray well-bedded marble with a few massive white beds Metamorphic minerals common
White member - White-to-gray massive marble and bedded marble Very little tremolite wollastonite, and diopside
Gray member - Gray-to-white, fine-to-coarse grained marble Tremolite, wollastonite, and diopside-rich zones
PRE-CARBONIFEROUS(?)
Chicopee Formation
Upper white member - Massive, white quartzite Metamorphosed pebble-bed 100 feet from top
Cross-laminated member - Gray-to-dark gray cross laminated quartzite Basal 200 feet composed of white-to buff feldspathic quartzite and micaceous quartzite
Ripple-marked member - White quartzite and gray micaceous quartzite Ripple marks 50 feet from base
Lime silicate member - White-to-buff quartzite with interbedded lime silicate rocks
THRUST PLATE
Saragossa Quartzite
Massive white-to-buff quartzite, highly fractured and faulted
THRUST PLATE
PRE-CAMBRIAN(?)
Baldwin Gneiss
Gneiss and augen gneiss Two ages of pre-Mississippian granitic intrusives
Vertical Scale
0 1000 2000 Feet

Figure 2. Generalized stratigraphic column, Johnston Grade area.

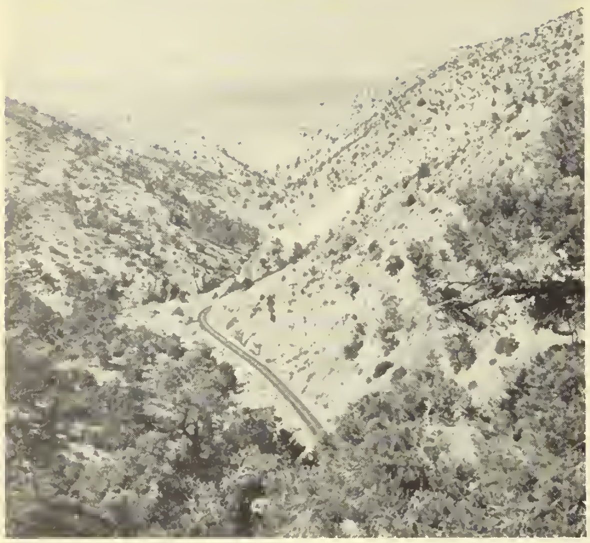

FIGURE 3. Cushenbury Canyon. Furnace limestone on both sides. Lucerne Valley in distance. Canyon follows trace of Helendale fault.

Baldwin Gneiss

The oldest formation in the Johnston Grade area is the Baldwin gneiss, most extensively exposed east of Baldwin Lake, which is here designated the type locality. The gneisses and associated granitic intrusions of this area were included in the Saragossa quartzite by Vaughn (1922, p. 350). The totally different kind of rocks involved, the more intense metamorphism, and the injected character of the Baldwin gneiss denote a more complex history than the Saragossa formation. In addition to the Baldwin Lake exposures a small outcrop of gneiss is found at the head of Chicopee Canyon, and three small areas are mapped west of Whisky Springs.

The facies of the Baldwin gneiss vary in their resistance to erosion. The augen gneiss commonly decomposes readily and although several resistant outcrops are found, it generally forms rounded slopes. The granitic gneiss is slightly more resistant to erosion than the augen gneiss. The fine-grained meta-dikes are the most resistant rock of the formation and often stand out several feet above the surrounding gneiss.

The Baldwin gneiss is composed chiefly of fine-grained gneiss and schist, and augen gneiss. Only in the most southerly portion of the area is any quantity of intrusive material associated with the gneiss.

The "eyes" of the augen gneiss reach a maximum length of over 2 inches in the plane of foliation. They are seldom more than three-quarters of an inch thick when measured across the foliation. Most of the larger augen are composed of fine-grained aggregates of quartz (70-40 percent), sericite (20-40 percent), and orthoclase (0-20 percent). In the smaller augen, coarse granoblastic quartz is commonly the only constituent. These lens-shaped aggregates, both large and small, are surrounded by a fine-grained (less than 0.5 millimeters) black matrix composed of mica, quartz, feldspar, and black opaque minerals. Muscovite composed of 20-40 percent of the matrix, biotite 30-60 percent, and magnetite 10-30 percent. Quartz and feldspar in the approximate ratio of 3:1 seldom form less than 20 percent of the matrix and occur in all amounts up to the point of becoming augen. Sphene, apatite, and zircon, are present in minor amounts. In some of the more uniform gneisses, broken, saussuritized, and quartz-intergrown plagioclase crystals may be recognized.

The transition from augen gneiss to fine-grained gneiss and schist may be gradational or the contact may be sharp. The gradational transition is brought about by a reduction in size and coalescing of the augen and matrix into light and dark bands.

In the southern portion of the area, many orthoclase-rich, lens- and pod-shaped pegmatites are in the gneiss. Here as much as 50 percent of the gneiss is granitic in composition.

Several 10- to 20-foot metamorphosed granitic dikes cut obliquely across the gneiss-granitic gneiss transition zone. They are gray to buff, locally reddish, very fine-grained igneous rocks which show little change in character along their outcrop. These granitic dikes are younger than both types of gneiss but are never found intrusive in the Paleozoic meta-sediments. For this reason they are included in the pre-Cambrian (?) complex.

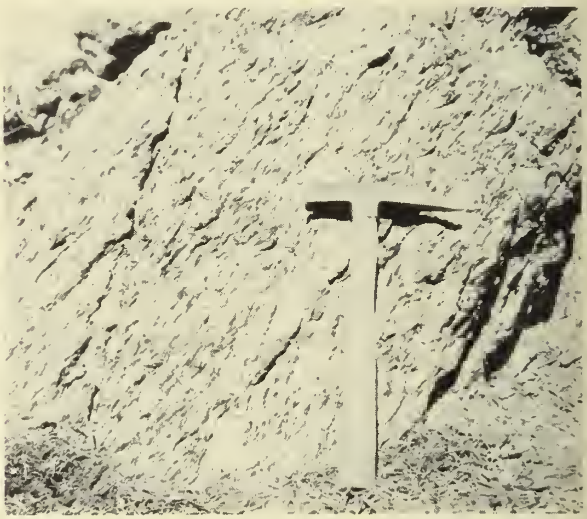

FIGURE 4. Augen gneiss facies of the Baldwin gneiss. Plane of foliation parallel to page. Maximum development of augen that of largest shown in photo.

The gneiss is in reverse fault contact with the Chicopee formation east of Baldwin Lake and also with the Furnace limestone to the south. West of the Doble mine the gneiss is in fault contact with cross-laminated quartzite of the Chicopee formation and overthrust by white Saragossa quartzite. North of Chicopee Canyon the gneiss is also faulted against the Chicopee formation. Cactus quartz monzonite intrudes the gneiss in this area but has little if any effect on the character of the gneiss.

The Baldwin gneiss was not studied in sufficient detail to permit an accurate statement as to its original character. From its general appearance, however, it is believed to represent a series of siliceous sediments that were intruded and metamorphosed by at least two different granitic magmas. The entire complex was then subjected to a later metamorphism. It is not known whether this second stage is the same regional metamorphism which affected the Paleozoic sediments or whether it took place before the deposition of the Saragossa, Chicopee, and Furnace formations. On the basis of the recognizable complex pre-Mississippian history of the Baldwin gneiss, it is assigned an early Paleozoic or pre-Cambrian age.

Saragossa Quartzite

The white quartzites, cross-laminated quartzites, and gneisses of the Bear Valley region were grouped together as the Saragossa quartzite by Vaughn (1922, p. 357). The gneisses by reason of their distinctly more complex history have been described above as a separate formation, the Baldwin gneiss. In this report, the quartzites of the area are divided into two formations, the Saragossa quartzite and the Chicopee formation, which are separated by a thrust fault. The quartzite of the thrust plate is called the Saragossa quartzite because it is similar in lithology to the type Saragossa and crops out continuously from Baldwin Lake to the type locality, Saragossa Springs. The quartzites beneath above the thrust plate are designated the Chicopee formation.

The Saragossa quartzite crops out along the southwest border of the area from Baldwin Lake to just west of Chicopee Canyon. In the latter area the thrust fault between the Saragossa quartzite and the Chicopee formation could not be traced because both formations are represented by white quartzite. West of Baldwin Lake, just outside the area mapped, massive white to buff quartzites with less than 20 degree dip are exposed on Gold Mountain. The Saragossa quartzite may be over 1000 feet thick if the section here is not duplicated by faulting. Widespread fracturing of the quartzites between Gold Mountain and Baldwin Lake was observed, and although it was impossible to trace them in the quartzite, or to determine their offset, at least three faults were found in this area. Only the white quartzites of the Chicopee formation are as resistant to erosion as the Saragossa quartzite. Figure 5 shows the cliff-and-woodland landscape that is typical of the Saragossa quartzite. A fault in the middle of the picture is evidenced by the abrupt change in dip of the beds from 25 degrees west to flat-lying.

The Saragossa quartzite beds are characterized by vague bedding, glassy fracture, and iron-stained appearance. Cross-laminations are rare and ripple marks were not observed in this formation. Grain size varies from 2 millimeters to submicroscopic, the majority of the rock being composed of grains less than 0.5 millimeters in diameter. The quartzite is typically iron-stained, the coloration occurring along bedding planes, or more commonly, in fractures. The larger fractures are sealed by veins of massive or interlocking crystal aggregates of quartz. Crystal size in these veins varies from submicroscopic to 10 millimeters in diameter. In the Doble mine, gold is associated with the hematite filling of the vein cavities. Pyrite occurs disseminated in the quartzite west of Baldwin Lake.

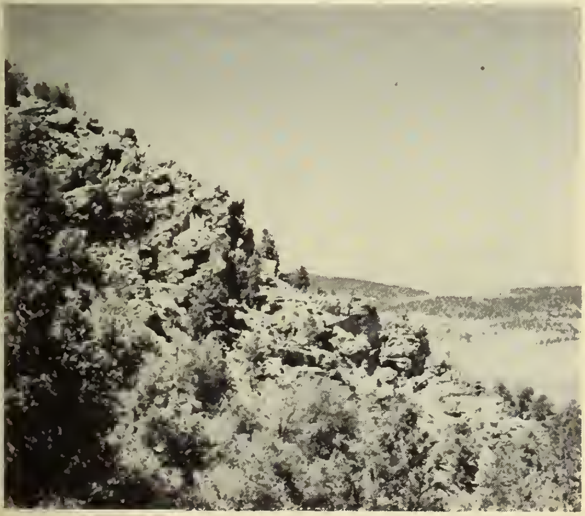

FIGURE 5. Saragossa quartzite west of Baldwin Lake.

In the Johnston Grade area the Saragossa quartzite is only found in a thrust plate which overlies the Baldwin gneiss and the Chicopee formation. At the head of Chicopee Canyon, just west of the area mapped, a small block of Furnace limestone lies in the thrust zone.

The age of the Saragossa quartzite is not known. It is believed to be older than the Carboniferous Furnace limestone and is therefore assigned to a pre-Carboniferous age. On the information available at present the Saragossa quartzite cannot be correlated with any other rocks in the general area.

Chicopee Formation

The Chicopee formation includes the lime silicate-bearing quartzites, white quartzites, and cross-laminated quartzites which crop out beneath the Saragossa thrust in Chicopee Canyon. These rocks are also found along the ridge east of Baldwin Lake from the mouth of Chicopee Canyon to the south edge of the area. The formation is not found east of the latter area. Chicopee Canyon is designated as the type locality of the Chicopee formation.

The white quartzite beds of the Chicopee formation are more resistant to erosion than any other rock type in the area and thus provide good exposures over much of the region. The other quartzite members, while not as resistant as the white quartzite, are more resistant than the other formations in the area.

Four members of the Chicopee formation were mapped in Chicopee Canyon. The complicated structure north of the canyon and the limited outcrops south of the canyon necessitated mapping the quartzite in the remainder of the area as undifferentiated Chicopee. In order of decreasing age, the members of the Chicopee formation are: lime-silicate member, ripple-marked quartzite member, cross-laminated quartzite member, and upper white quartzite member.

The lime-silicate member crops out in Chicopee Canyon and to the northwest. It consists of approximately 350 feet of metamorphosed quartzite, limestone, and transitional material. Lime-rich rocks make up about 25 percent of this member.

The lowest rock exposed in Chicopee Canyon is composed of equal quantities of diopside and quartz with rare crystals of calcite and magnetite. The diopside occurs as distinct grains up to 1 millimeter in diameter while the quartz is present as ragged, recrystallized grains of less than 0.02 millimeters in diameter. Figure 6 illustrates the poor preservation of the original texture of this rock. A rock containing 80 percent calcite and 20 percent diopside is found a few feet west. Intercalated with it is a rock of moderately rounded quartz grains in a calcareous matrix, the quartz completely recrystallized but the grains retaining their original shape. Although the matrix is for the most part indeterminable, a little biotite, sphene, and

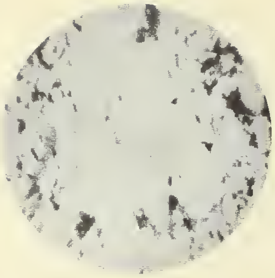

FIGURE 6. Gray quartzite in lime-silicate member of Chicopee formation. Plane-polarized light. Bedding planes marked by biotite concentrations in horizontal position. Fractured tourmaline crystal at top of picture. Magnification 18x.

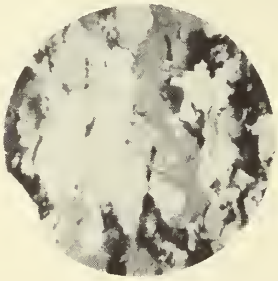

FIGURE 7. Gray quartzite in lime-silicate member of Chicopee formation. Crossed nicols, same orientation as fig. 6. Slight tendency toward schistosity in recrystallized quartz. Magnification 18x.

highly altered plagioclase can be recognized. Most of the matrix appears to consist of fine-grained carbonate minerals.

Near the top of the lime-silicate member is a very fine-grained quartzite consisting of 80 percent quartz, 15 percent plagioclase, 5 percent muscovite and biotite. Zircon, sphene, and tourmaline occur rarely as broken grains, indicating that they were original constituents of the metamorphosed sediment. Rhombohedral plates of hematite are also present. The broken crystals of accessory minerals and the granoblastic quartz indicate that these quartzites have been sheared and recrystallized. Photomicrographs (figs. 6 and 7) show a sheared tourmaline crystal and the recrystallized nature of the quartzite.

The ripple-marked member of the Chicopee formation, in contrast to the lower member, is composed almost entirely of quartzite. The basal 50 feet is pure, white, platy, quartzite with individual beds varying from 1 inch to 8 inches in thickness. Near the top of the white quartzite a widespread persistent zone of ripple marks is found. While the amplitude of most of the ripple marks is from an eighth to a quarter of an inch, a few specimens show an amplitude of nearly three-quarters of an inch. The length ranges from half an inch to more than 2 inches.

Above the basal unit of the ripple-marked member is approximately 150 feet of white, buff, and gray quartzite with a minor amount of intercalated dark micaceous quartzite. The light-colored quartzite is similar to the lower white quartzite except that it shows faint cross-lamination and has more abundant feldspar and mica. The plagioclase is between oligoclase and andesine in composition and commonly makes up 30 percent of the rock. Muscovite is the chief mica, making up 5 to 15 percent of the total rock. Ferromagnesian minerals are not common in the lighter quartzite beds, seldom comprising more than 5 percent. In the darker quartzite beds they make up a third of the rock. The original shapes of the grains have been destroyed by recrystallization.

Since the boundary between this member and the overlying cross-laminated member is transitional, as is the case with all members of the Chicopee formation, the top of the ripple-marked member is taken to be the base of a 15-foot massive, black, fine-grained quartzite.

More than 450 feet of gray to black quartzite is included in the cross-laminated member of the Chicopee formation. The rocks can be distinguished from the other members of the formation by their darker color and almost universally well-developed cross-laminations.

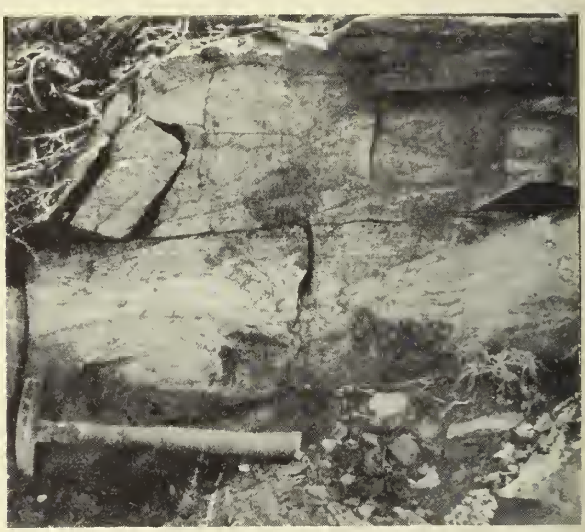

FIGURE 8. Overturned cross-lamination in Chicopee formation.

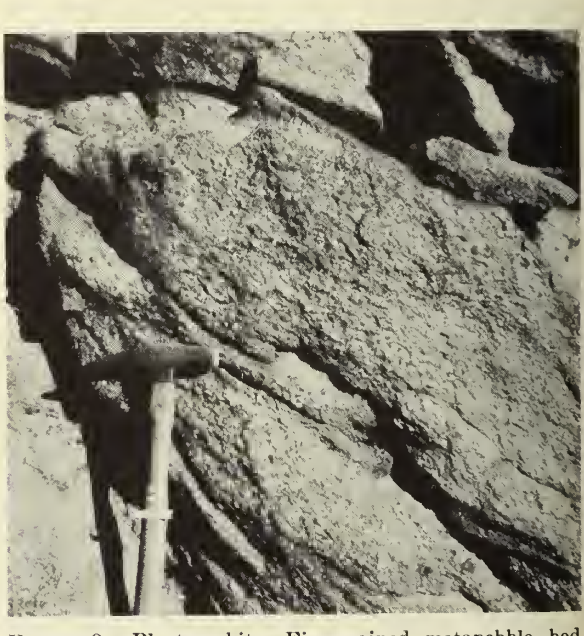

FIGURE 9. Blastosephite. Fine-grained metapebble bed. Specimen in fig. 11 was taken from this outcrop. Cross-laminated member of Chicopee formation.

The basal 50 feet is dominantly dark-gray to black uartzite whose color is the result of containing as much s 30 percent biotite and black opaque minerals. Feldspar, hiefly oligoclase, is more abundant than quartz, and these ight minerals make up the majority of the rock, occurring s small grains (less than 0.1 millimeter) that are not pparent in the hand specimen because biotite flakes are ent around them. The feldspar shows considerable altertion and the quartz appears to be recrystallized.

Above the fine-grained basal section of the cross-laminated member is 150 feet of gray to buff quartzite and etamorphosed pebble conglomerate. The original texture apparent only in the coarser-grained rocks. In these, he subrounded to rounded quartz grains of 1 to 20 millieters diameter are surrounded by a biotite-rich matrix f quartzite. The coarse grains are present in all proporons from 10 to 90 percent of the rock. When the large rains form a minor proportion, the rock is commonly ross-bedded and shows graded bedding. In thin section, owever, the effects of shearing are very noticeable. Alhough they preserve their original outline, over 95 pernt of the granules or pebbles are recrystallized, the emaining grains being severely strained. The shearing post-depositional as evidenced by the extreme granulaon of grains in zones of more intense shearing, and by e granulation of only the adjoining edges of granules tween which shearing has been localized. The matrix the conglomerates includes up to 30 percent mica, biotite ominant over muscovite, a few percent black opaque inerals, the remainder very fine-grained granoblastic artz.

In the gray-to-buff quartzite the original texture of the ck has been obliterated. In the hand specimen the rock pears to be composed of glassy quartz and feldspar ains (up to 2 millimeters in diameter) set in a submioscopic matrix with dark minerals concentrated in reaky clots. Under the microscope these relations are rified, the quartz being completely recrystallized. The atrix is a granoblastic aggregate of quartz and muscovite. In some cases biotite is concentrated along bedding planes and gives a foliation to the rock.

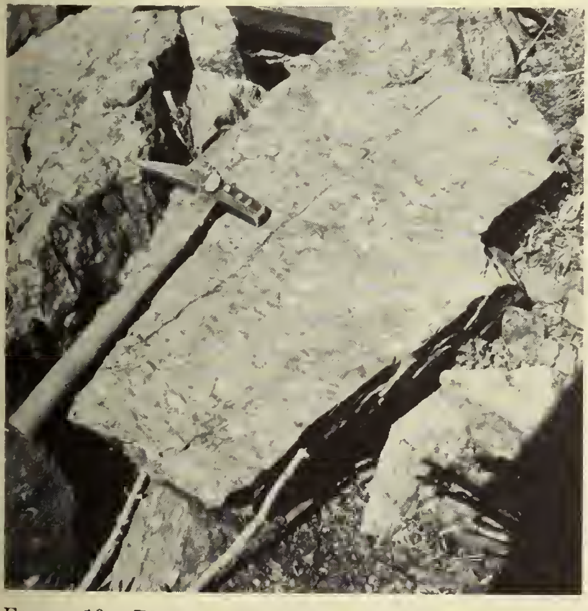

Figure 10. Blastosephite. Coarse-grained metapebble bed 100 feet from top of upper member of Chicopee formation.

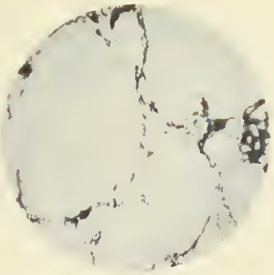

Figure 11. Blastosephite. Plane-polarized light. Pebbles are subrounded with very little interstitial material. Magnification 18x.

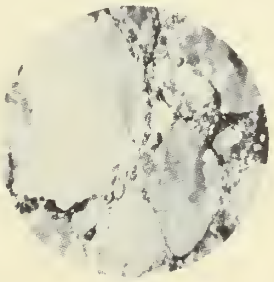

Figure 12. Blastosephite. Crossed nicols. Same orientation as fig. 11. Grain in upper center shows typical granoblastic texture of pebbles. Shear concentrated through center of picture.

The upper 250 feet of the cross-laminated member is a dark gray quartzite with pronounced black banding. The cross laminations are widespread but on small scale. Individual units or sets of beds are seldom over 18 inches long and 6 inches thick. The angular discordance between a series of laminae and those truncating it ranges up to 90 degrees, the most common being about 30 degrees. Perfectly flat, well-bedded alternations are common, the sets of dark and light laminae being ¼ to over 1 inch in thickness. The grain size of these rocks is normally less than 1 millimeter.

The upper member of the Chicopee formation is dominantly a white to buff massive quartzite. Less than 150 feet of this upper member are believed to be represented in the normal section in Chicopee Canyon beneath the Saragossa thrust fault.

The quartzite of the upper member is distinguished from the thin-bedded quartzites of the ripple-marked member by its vague bedding, glassy fracture, and iron-stained appearance. Rare cross-laminations are observed but ripple marks are entirely lacking. Grain size varies from 2 millimeters to submicroscopic, the majority of the rock being composed of grains less than 0.5 millimeter in diameter. The upper member is commonly iron-stained, the coloration occurring along bedding planes and fractures.

About 100 feet from the top of the upper member is a thin, distinct bed of coarse, pebbly, buff conglomerate. The pebbles are recrystallized quartz up to an inch in diameter and 3 inches long and are set in a matrix of micaceous quartzite.

All contacts between the Chicopee formation and the Baldwin gneiss are faults with the exception of the area north of Chicopee Canyon where at two localities the quartzite overlies the gneiss by what may be a depositional contact. The poor outcrops and the complexity of the faulting in this area make it impossible to determine the nature of the contact.

White quartzite of the Chicopee formation stratigraphically underlies the gray marble of the Furnace limestone just west of the Cactus Flat-Smarts Ranch area. The quartzite and marble beds in this area are conformable and for this reason the contact is mapped as a normal depositional contact.

In the vicinity of the Johnston Grade, in Chicopee Canyon, and west of Whisky Springs, the Chicopee formation is intruded by the Cactus quartz monzonite. Contact effects in these locations are limited to a slight bleaching of the quartzite and an increase in the size of the recrystallized quartz grains.

The composition of the Chicopee quarzites, their characteristic cross-lamination, and the presence of ripple marks are clues to the paleogeographic conditions existing at the time of their deposition. The large amounts of feldspar and mica scattered throughout the section indicate that these sediments are not the product of the extreme weathering conditions envisioned by Krynine (1941, p. 1915) as existing during the Cambrian when the Uinta and other high-quartz sandstones were deposited. The composition of the sediments in general seems to indicate a normal humid climate. Sedimentary features of the Chicopee formation, the cross-lamination and ripple marks, are indicative of deltaic or at least near-shore deposition.

The age of the Chicopee formation is not known. No fossils were found in the area mapped and due to the widespread recrystallization of the quartzites it is doubtful if fossils ever will be found. The only basis for age determination of the Chicopee formation is in its relation to the Furnace limestone. Assuming the contact between the two formations to be depositional, the Chicopee formation is the older because it stratigraphically underlies the Furnace limestone. As the Furnace is Carboniferous, the Chicopee may be considered Mississippian or more probably pre-Carboniferous. At the present time the Chicopee formation can not be correlated with any other rocks in the general area.

Furnace Limestone

The thick section of marble forming the north wall of the San Bernardino mountains from Crystal Creek to Blackhawk Mountain was named the Furnace limestone by Vaughn (1922, p. 355), the type locality being Furnace Canyon, 3 miles west of Cushenbury Canyon. Woodford and Harriss also reported on these rocks in their Blackhawk Canyon paper of 1928.

The Furnace marble forms both walls of Cushenbury Canyon from the edge of the Mojave desert to north of Whisky Springs. The formation gives rise to steep-walled cliffs and to talus aprons which slope more than 50 degrees. East of Cushenbury Canyon, from Monarch Flat to Blackhawk Mountain, the marble is closely fractured and is responsible for hummocky landslide topography superimposed upon normal mountain slopes. These characteristic landslide forms are found ranging in size from the quarter-square mile depression of Monarch Flat to 3- or 4-foot hummocks forming on the sides of the ridges.

A thin band of Furnace limestone is exposed near the base of the ridge northeast of Baldwin Lake, more or less continuously from the mouth of Chicopee Canyon to the south edge of the area. Several roof pendants of the marble are exposed resting on Cactus quartz monzonite east of the Johnston Grade. In this area the marble is more resistant to erosion than the quartz monzonite.

The Furnace limestone is subdivided into three members; the gray, white, and black members. The stratigraphic position of only the basal gray member is known This member crops out beneath the Chicopee formation in the overturned and faulted limb of the anticline southwest of Cactus Flat. Because of the close similarity between these gray rocks and those in the roof-pendant area east of the Johnston Grade, the latter are included in the gray member, even though they are on opposite sides of the Helendale fault. The white and black members are separated from the basal gray member by grantic intrusions and faults and their relative age is not known with certainty. Northeast of Burnt Flat the black member stratigraphically overlies the white, judging by the crossbedding the marble west of Burnt Flat. The faulted and highly fractured marble of Blackhawk Mountain is mapped as Furnace limestone, undifferentiated.

The gray member is exposed continuously from the mouth of Chicopee Canyon to the south border of the area except at the Johnston Grade where an intrusion of Cactus quartz monzonite eliminates it. The weathering color of the gray member ranges from pale gray to dark gray; a few beds are brown or buff. On the fresh surface the gray member is seen to be predominantly gray, with some buff, white, and dark gray layers. A common type is a gray marble with white streaks or clots which have the appearance of augen when coarse. The color and mineralogy of the gray member, although not uniform, are not sufficiently varied to permit the mapping of individual beds in the body of the marble.

A discontinuous but fairly uniform mica-schist zone reaching a maximum thickness of 50 feet, is found in gradational contact with the Chicopee formation. Thes rocks are composed of carbonate, sericite, biotite, and quartz, and are silver-gray in the hand specimen. Nea the mouth of Chicopee Canyon an intrusion of Cactus quartz monzonite has converted the mica schist to a dark gray spotted schist. The square white spots are believed to be cross-sections of highly altered chiastolite-andulasit crystals which are now composed of plagioclase, muscovite, black opaque minerals, some remnants of andalusite, and a little tourmaline. These white areas are from 1 millimeter to 5 millimeters square, and up to 20 millimeters long, and although the average is 20 percent, they may constitute as much as 50 percent of the rock. Th body of the schist is composed of muscovite and biotite, in the ratio of 3:1, and much less than 10 percent quartz opaque minerals and tourmaline.

Well over 95 percent of the gray member consists o coarse-to fine-grained recrystallized carbonate material Throughout its exposure the rock contains scattered zone rich in tremolite which occurs in the form of needles up to 2 millimeters wide and 15 millimeters long, lying in planes parallel to the bedding. Fine fibrous aggregates o ollastonite are also observed in the hand specimen. In iin section most of the marble specimens are seen to ontain scattered grains of diopside, quartz, and mus- ovite, in order of abundance. Zones rich in diopside and ollastonite (as much as 20 percent of the rock in places) em to have little relation to surface outcrops of igneous ocks. The typical dolomite uneven weathering surface nd widespread occurrence of diopside testify to the pres- nce of magnesium in the rock but no highly dolomitic eds were observed.

Along the south border of the area a thickness of over 00 feet may be accounted for if a uniform dip is assumed om the northeast to the Helendale fault and from the ult to the Furnace contact with the quartzite.

The white member, chiefly composed of white and light ay massive marble, is exposed north and east of Burnt lat. Individual beds range in thickness from a few ches to over 20 feet. It is generally coarse-grained, the erage grain size being between 2 and 4 millimeters. An ceptionally coarse-grained white variety lies 1500 feet st of the Mohawk mine. Many of the calcite crystals in is bed are over 5 centimeters in diameter.

Quartz, diopside, and wollastonite are much less oundant in the white member than in either the gray or ack members. North of Burnt Flat where the marbles p about 45° SW., over 2000 feet of the white member the Furnace formation are exposed.

Marble of the black member of the Furnace limestone ops out between the white member and the Helendale ult. It is predominantly dark gray, although perhaps a urth of this member is gray to white. Thin bedding, ne-grained texture, and brown iron-rich layers are aracteristic. The brown bands are more resistant to osion than the body of the marble and may protrude ore than 5 millimeters on the weathered surface. Small millimeter to 2 millimeters) brown clots give some cks of this member a salt and pepper appearance.

The resistant brown bands are composed of quartz, opside, and wollastonite-rich areas, the color being due iron oxide. These minerals are very common in the ack member comprising as much as 25 percent of the ck, while in the brown bands they may total 50 percent.

The marble beds exposed on Blackhawk Mountain were apped as undifferentiated Furnace limestone for two asons: the complex fracturing and faulting of the cks, and the lack of distinctive marker beds in the rnace limestone. Most of the marble on Blackhawk ountain appears similar to the basal gray member. Mas- e white and gray beds are not uncommon, however, and now-white marble has been quarried intermittently for veral years in Cushenbury Canyon. While the miner- gy of the undifferentiated rocks is much the same as s been described for the other members, wollastonite is ore widespread.

The numerous faults and fracture zones are often rked by veins of galena or a rose-colored staining of fractured rock.

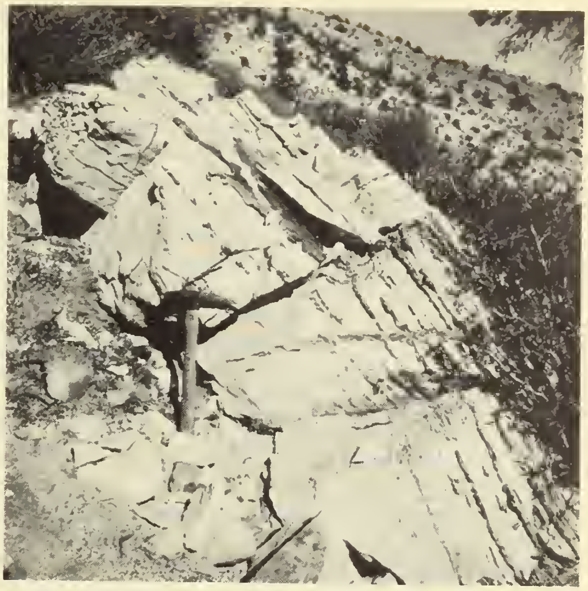

Figure 13. Contact-metamorphosed marble on Blackhawk Mountain. Dark areas, metamorphic minerals; light areas, calcite and diopside.

Contact Metamorphism. The intruding Cactus quartz nzonite has commonly developed 1- to 5-foot tactite nes in the Furnace limestone roof pendants in the area t of the Johnston Grade. This tactite consists of heden- gite and garnet with varying amounts of epidote, artz, calcite, and wollastonite. Ore minerals found in- de scheelite, molybdenite, and pyrite. In many places the tactite zone is very thin and the transition from granitic rock to marble may be observed in a single hand specimen. A thin section of a tactite-to-marble transition showed the following zonation in a distance of half an inch.

Calcite and scattered grains of diopside and quartz. (Several of the quartz grains rimmed with diopside.)
Interfingering contact.
Epidote, red-brown garnet, and iron oxide.
Interfingering contact.
Calcite, garnet, hedenbergite, and black opaque minerals.

An examination of a specimen from the middle of one of the roof pendants showed it to be composed of roughly 80 percent calcite, the remaining 20 percent being wollastonite, colorless garnet, black opaque minerals, quartz, and diopside. All of the metamorphic minerals but diopside are concentrated in narrow bands, the diopside being scattered throughout the rock. Since the calcite occurs as elongated granoblastic crystals the rock should be called a calc-silicate schist.

The quartz diorite intrusions in the roof-pendant area, and in the area south of Blackhawk Mountain, have had a similar contact effect on the marble they intrude. The skarn zone in the latter area is not as well developed as in the former. Figure 13 shows a contact metamorphosed marble in which the metamorphic minerals are concentrated in bands up to half an inch wide. The bands, which weather brown, are composed of wollastonite, garnet, quartz, and opaque minerals. The white areas are composed of calcite and diopside.

The contact metamorphic zone between the Cactus quartz monzonite and Furnace limestone is up to 8 feet wide at the Mohawk mine. It strikes S. 60° W. and is almost vertical. Pyrite, sphalerite, galena, cerussite, and minor quantities of gold and silver are associated with garnet and pyroxene. The pyrite occurs as masses up to 6 inches long.

Age. While no fossils were found in the area mapped, questionable Mississippian fossils have been found about 6 miles to the west at Crystal Creek (Woodford and Harriss, 1928, p. 270). More recently, McCulloh (1950, personal communication) collected a Pennsylvanian crinoid stem from the limestone northwest of Holcomb Valley. These fossil localities are in limestone or marble which is similar in appearance to the marble of the Johnston Grade area, and to that which crops out almost continuously from Crystal Creek to Cushenbury Canyon. As the stratigraphy of the Furnace limestone has not been worked out and even the approximate position of the fossil horizons in the section is not known, the Furnace is dated as Carboniferous in age.

Cactus Quartz Monzonite

The term Cactus granite was applied by Vaughn (1922, p. 365) to a medium- to coarse-grained granite exposed in Cactus Flat and to most of the other bodies of granitic rocks exposed in the San Bernardino Mountains. Near Whisky Springs and in Blackhawk Canyon, Vaughn described two pegmatite-cut diorites as heterogeneous plutonic rocks and suggested that their age might be pre-Cambrian. Woodford and Harris (1928, p. 272) considered the gneissic rocks of Blackhawk Canyon to be merely early crystallized Cactus granite whose gneissic structure was induced by flowage. The writer believes all of the above intrusive rocks to be phases of one igneous mass. Since they vary from granite and aplite to diorite and are chiefly quartz monzonite, the term Cactus quartz monzonite is suggested as a more descriptive name.

In the Johnston Grade area these granitic rocks are found on the northeast boundary extending from Whisky Springs to Smarts Ranch. The north border of this mass extends from Grapevine Creek almost due west to Burnt Flat. Several small intrusions were mapped north of Baldwin Lake.

With the exception of the ridges west and south of Cactus Flat, the Cactus intrusives weather deeply, forming relatively flat areas of low relief. The ridge south of Cactus Flat is formed by resistant quartz monzonite which rises over 300 feet above the general surface of the area.

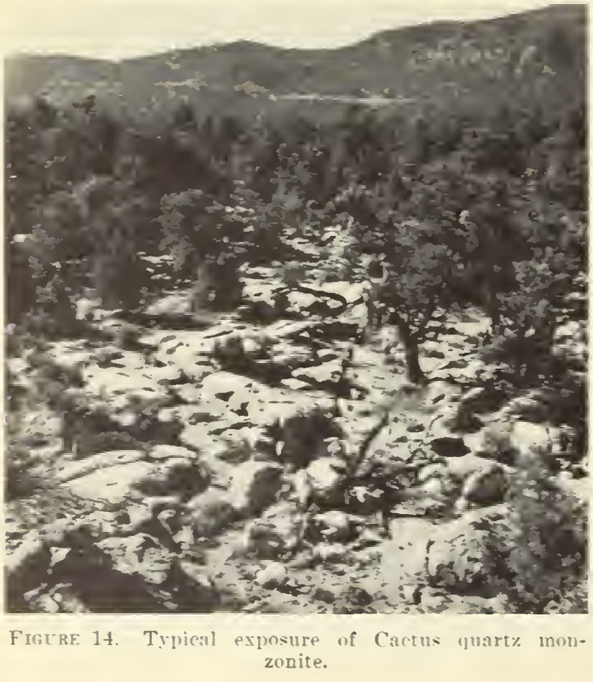

FIGURE 14. Typical exposure of Cactus quartz monzonite.

The Cactus quartz monzonite intrudes Baldwin gnei west and southwest of Whisky Springs. In the same ge eral area it is found truncating the Chicopee formatio and Furnace limestone. At the Mohawk mine, a 1- to foot sulfide and carbonate zone is found on the marbl igneous contact. From Whisky Springs to Grapevi Creek and a mile and a half south of Grapevine Creek, dioritic phase of the intrusion invades marble of the Fu nace formation. From the latter point southeast to Smar Ranch the marble is cut by quartz monzonite. Near t Johnston Grade, the Chicopee and Furnace formatio are intruded by several smaller masses of granitic rock The contact effects of the Cactus quartz monzonite on t rocks it invades have been covered in the discussion of t older rocks.

The three facies of the Cactus quartz monzonite diffe entiated in this report are, in order of their age of e placement from oldest to youngest: aplite; quartz diorit and quartz monzonite.

The fine-grained, buff, intrusive rock cropping out the west and to the north of Whisky Springs is mapp as Cactus quartz monzonite, aplite facies. It intrud marble of the Furnace formation causing the formati of a thin contact zone and is itself cut by the quartz diori and quartz monzonite of the Cactus granitics. West Whisky Springs the outcrop of aplite includes quart orthoclase-plagioclase pegmatites.

The weathered surface of the aplite is red-brown, color which penetrates an inch or two into the rock fro all fractures. The fresh color of the aplite is buff. Litt about the mineralogy and texture can be determined wi the hand lens except to note small feldspar phenocryst In thin section the rock shows the effect of shearing. I stead of being xenomorphic as is expected in an aplit the quartz grains are granoblastic. Sphene occurs as clo and trails of xenomorphic grains. Oligoclase is seen well-twinned crystals of the same size as the quartz a also as larger relicts. Here and there, randomly orient crystals of plagioclase form masses several times the si of the average grains. They are believed to represent r crystallized phenocrysts. A rough estimate of mineral pe centages shows quartz 40 percent, oligoclase 30 perce orthoclase 20 percent, sphene, biotite, muscovite, a apatite, 10 percent.

The quartz diorite facies of the Cactus quartz mo zonite intrudes the Furnace limestone in the roof penda area northeast of the Johnston Grade and in the vicini of Whisky Springs. In these same areas the quartz diori facies is cut by the quartz monzonite of the main body the intrusion.

The color of the quartz diorite varies from gray to most black as the ferromagnesian content of equal prop tions of biotite and green hornblende vary from 30 pe cent to 60 percent. Both biotite and hornblende sh incipient alteration to chlorite, the hornblende being t more severely attacked. Quartz is present in all variet of the quartz diorite, constituting from 10 percent to percent of the rock. The quartz was late in crystalliz and displays a fresh, almost granoblastic appearance. T most abundant mineral in the quartz diorite is plagiocla of andesine composition. The anorthite content of t centers of the most strongly zoned crystals reaches 60 pe cent. In an average specimen plagioclase constitutes o one-half of the rock while in the most mafic varieties it

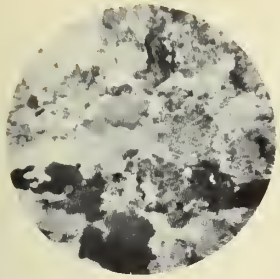

Figure 15. Cactus quartz monzonite, quartz monzonite facies. Crossed nicols, magnification 18x. Specimen from ridge south of Cactus Flat showing scattered garnets and granoblastic texture of sheared rock.

30 percent of the total. The entire plagioclase crys-
, and especially the cores, show the effect of saussuri-
tion. Orthoclase is a minor constituent, its proportion
ly exceeding 10 percent. Myrmekite intergrowths are
ent but not abundant. Sphene is the chief accessory
eral, sometimes totaling 5 percent of the whole. Mag-
te and ilmenite occur in small quantities.

the Whisky Springs area the quartz diorite has been
by many pegmatites rich in pink orthoclase and
rtz. These dikes also cut the aplite facies in the same
.

he most abundant igneous rock in the area is a coarse-
ned, buff to gray, binary granitic rock which has
it equal amounts of plagioclase and orthoclase. Oligo-
, An_{20}, in moderately well formed crystals twinned
rding to the Carlsbad and Albite laws, is slightly more
ndant than later-crystallizing orthoclase in most of
sections examined. Zoning of the plagioclase is not
ked although a tendency toward transitory extinction
be noted in a few of the crystals. Myrmekitic inter-
vths are found between some of the oligoclase and
oclase crystals. Incipient saussuritization of the pla-
lase is evidenced by a clouding of the crystals and by
ute sericite flakes forming along cleavages. Between
nd 35 percent of the rock is oligoclase.

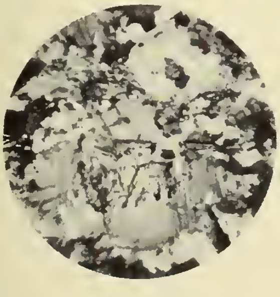

Figure 16. Cactus quartz monzonite, quartz diorite facies. Crossed nicols, magnification 18x. Cores of plagioclase crystals highly altered.

thoclase, composing 25 percent to 30 percent of the
, is usually found as small anhedral interwoven grains
h crystallized later than the plagioclase. The thin
on of a sample from the small intrusion east of Doble
ved large orthoclase crystals dominating plagioclase
ratio of 3:2. The orthoclase also differs from the pla-
lase in that it is much less altered. Microcline grid
ning is observed on less than 10 percent of the potash
spar.

Clear, colorless, anhedral quartz consistently makes up about 40 percent of the quartz monzonites examined; with the orthoclase it forms the matrix in which the larger plagioclase crystals are found. The quartz characteristically occurs as wormy and shapeless blebs in orthoclase and in larger quartz grains; strain shadows are common.

Both biotite and muscovite are found in minor amounts, usually composing less than 10 percent of the rock though rarely they may make up 15 percent. More often than not, muscovite is the predominant mica. Zircon, apatite, garnet, and sphene are of minor importance in the quartz monzonite facies as a whole, but in some places they are abundant. Red garnet is the most widespread accessory mineral, rarely comprising as much as 5 percent of the rock.

Of considerable interest are the cataclastic and protoclastic textures of the quartz monzonite. To the east of the Mohawk mine, on the ridge south of Cactus Flat, and at various places in the roof pendant area, sheared and lineated igneous rocks are found. These rocks correspond in composition to the above types but their texture is characteristic. Feldspar and quartz grains are fractured, mica flakes bent and shredded, garnets, zircons, and sphene crystals are broken and occasionally post-deformation microcline is found healing fractures. Strain shadows are present on almost all the quartz grains. These textures indicate that the nearly crystallized rocks were subjected to stress as they were being emplaced. A detailed petrographic study of the Cactus quartz monzonite should be able to ascertain whether this forceful injection is a local feature or a characteristic of the intrusion as a whole.

Quaternary Sediments

Fanglomerate

Most of the fanglomerate is found along the base of the ridge northeast of Baldwin Lake. In places it has been cut by the Helendale fault. From Cactus Flat to the Johnston Grade, the coarse fragments of the fan consist almost entirely of angular quartzite. Very few pieces of marble or quartz monzonite are found in the fan gravel. The position of these quartzite-rich fans beneath marble and quartz monzonite outcrops is an indication of the recency of movement along the Helendale fault. South of the Johnston Grade the fanglomerate is composed of marble, quartzite, and schist. Due to the high marble content the soil here is gray to black, in contrast to the quartzite fanglomerate where the high iron content causes the soil to be red brown.

The lower slopes of Gold Mountain have an apron of quartzitic fan material.

Alluvium

Alluvium is restricted to the flat east of the Johnston Grade and to the Baldwin Lake basin. In the former area, the alluvial deposits are chiefly derived from disintegrated Cactus quartz monzonite which crops out on the Johnston Grade. They consist of unsorted, angular, coarse-to-fine-grained sands, high in quartz and feldspar. The alluvium of the Baldwin Lake basin is fine grained and has a high clay content. North of the lake, the mill tailings of the Doble mine have been mapped as alluvium, although in places they are eolian deposits.

STRUCTURAL GEOLOGY

An overturned anticline and at least two distinct ages of faulting complicate the structure of the Johnston Grade area. The earlier faulting is believed to be associated with the folding. On the basis of age of faulting the area may be divided into two parts: the northeast half, where the faulting is post-Cretaceous; and the southwest half where most of the faulting occurred prior to the intrusion of the Cactus granitics.

Folding

The dominant structure west of the Helendale fault is an overturned anticline exposed in Chicopee Canyon. The axis of this anticline cuts across the canyon and generally follows the ridge north of Baldwin Lake. Overturned beds of the Chicopee formation are observed all along the ridge. In the south part of Chicopee Canyon the Chicopee formation has a normal position and 10-20° dip to the southwest. At the bend in the canyon the beds are vertical and then overturned as one proceeds down the canyon. The folding took place prior to the emplacement of the Cactus quartz monzonite.

Pre-Tertiary Faulting

High-Angle Faults

Doble Fault. The Doble fault, a steep reverse fault bringing Baldwin gneiss against beds of the Chicopee formation, may be traced from the head of Chicopee Canyon through Doble to the south boundary of the area. The gneiss is adjacent to cross-laminated quartzite in Chicopee Canyon and white quartzite from Doble to south of the Johnston Grade. Beyond the south border of the area gneiss is adjacent to the Furnace limestone. At the Doble mine and west of Chicopee Canyon the Doble fault is covered by the Saragossa thrust plate.

Chicopee Canyon Faults. In the lower portion of Chicopee Canyon the overturned limb of the anticline formed in the Chicopee formation has been broken by a high-angle fault which brings cross-laminated quartzites into contact with the uppermost quartzites of the Chicopee formation. About half a mile southeast of Chicopee Canyon the block to the east of this fault is cut by two cross faults which do not cut the west block. A well developed shear zone is found along the axis of the anticline but could not be traced across Chicopee Canyon. Near the Johnston Grade the similarity in lithology between individual beds of the Chicopee members prevented the distinguishing of the Chicopee Canyon faults from the faults of the Helendale system.

Low-Angle Faults

Saragossa Thrust. At the head of Chicopee Canyon a flat thrust, here designated the Saragossa thrust, causes massive white Saragossa quartzite to overlie the Baldwin gneiss-Chicopee formation fault contact. At three places on the road in this area intense shearing of the lower rocks is noted. Just west of the area mapped, a mass of Furnace limestone 100 feet long is exposed in the thrust zone. The quartzites of the Doble mine are believed to be part of the thrust which swings to the south and disappears beneath Baldwin Lake. The faulting and fracturing of the quartzites above this thrust in the area west of Baldwin Lake have been mentioned previously. The location of the Saragossa thrust west of Chicopee Canyon could not be accurately determined because white, massive Saragossa quartzite is thrust over white quartzite of the Chicopee formation. The approximate location of the thrust in this area is indicated by the presence of a distinctive coarse-grained meta-pebble bed within 100 feet of the top of the Chicopee formation in the overturned section. The absen of Furnace limestone in this area west of Chicopee Cany means that the thrust lies stratigraphically within 100 fe of the meta-pebble bed.

Faults West of Whisky Springs. Between Burnt F and Whisky Springs three thrust faults dipping west in the mountains are cut off by Cactus quartz monzoni This whole area is complexly faulted and only those fau that bring contrasting rock types into juxtaposition ha been mapped. Without question more faults occur in t Baldwin gneiss and in the undifferentiated portions the Chicopee formation. At several places in this ar small bodies of Cactus granitic rocks have intruded fa planes.

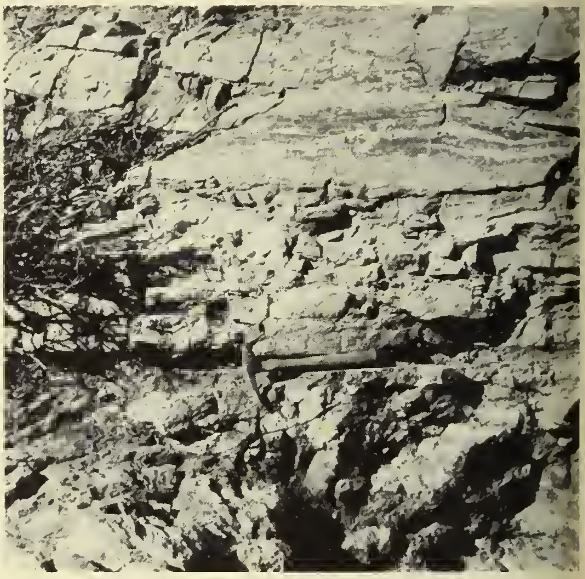

Figure 17. Fault in Furnace limestone on south slope of Blackhawk Mountain.

Late Cenozoic Faulting

High-Angle Faults

Helendale Fault. A vertical fault, which is an ext-sion of the Helendale fault, cuts through the center of e area from northwest to southeast. The Helendale fault, -scribed in detail by Bowen (in press) can be traced fr the Mojave River, at a point 2 miles north of Helenda, southeast through the Granite Mountains and acrs Lucerne Valley to the mouth of Cushenbury Canyon. Cushenbury Canyon the position of the fault is mark by highly sheared and contorted beds of Furnace li-stone. Just north of Whisky Springs the fault passes in the Cactus quartz monzonite and the trace may be f-lowed in these rocks by a line of springs, including Whisy Springs, and by the fault contact between granitic ros and fanglomerate west of Cactus Flat. In this area e fault is actually a series of braided, nearly parallel fau A shear zone in the Cactus monzonite, another faul granitic-fanglomerate contact, and shearing of the F-nace limestone, clearly mark the position of the Hel-dale fault on the Johnston Grade. Southeast of the Jo-ston Grade the fault follows the base of the ridge a has sheared the marble exposed in this area. There sees to be a continuous topographic expression of the Hel-dale fault to the southeast beyond the Rose mine a distance of over 6 miles.

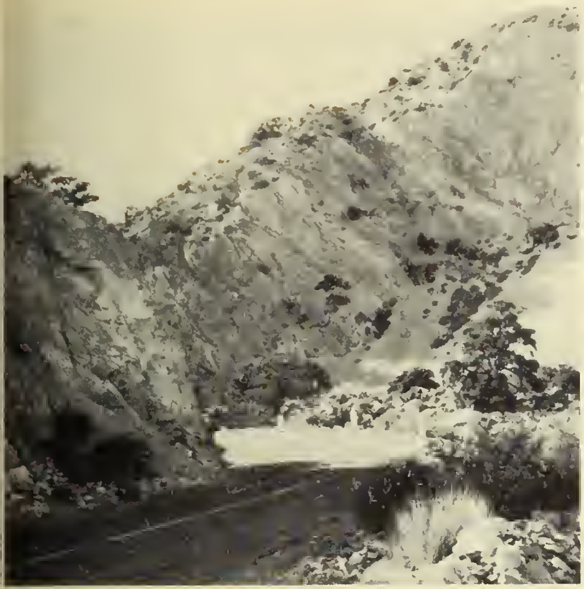

Figure 18. Helendale fault zone. Sheared Furnace limestone in Cushenbury Canyon.

he apparent displacement of the Helendale fault in Johnston Grade area is dip slip with the west block ing up in relation to the east block. It may be dated Quaternary, as it cuts the fanglomerates.

lackhawk Mountain Area. A well-defined high-angle rse fault is traceable along the south slope of Black- k Mountain from the east edge of the area to where s cut out by the Helendale fault north of Whisky ings. This fault has a 45° dip to the south along the boundary of the area. The relation of the fault blocks g this fault, north down and south up, is the same as been attributed to the thrust faults in Blackhawk yon by Woodford and Harriss (1928, p. 283) where itic rocks are thrust over late Cenozoic sediments. It ld appear that these three faults are part of a late ozoic fault zone which caused the brecciation of Black intain.

GEOMORPHOLOGY

andslides. The northwest slopes of Blackhawk Moun- are covered with fractured marble and landslide tle material. These two types of rock are so intimately ed that it is not possible to distinguish between them. y at Monarch Flat, the depression formed behind a e landslide, is it possible to map individual areas in the fractured mass. The slopes are characterized by e rounded ridges than are found in the solid marbles e west of Cushenbury Canyon. A close study reveals the slopes are actually hummocky on a small scale are almost completely formed of loose angular frag- ts. Even the top of Blackhawk Mountain displays this mocky irregular surface and a small landslide is d at the 6500-foot level on the west side of the moun- .

he name Blackhawk breccia has been applied by dford and Harriss (1928, p. 279) to rocks of this type osed in Blackhawk Canyon. This term is not used in report because in its original usage it was restricted ocks with a depositional origin. The presence of shattered marble and typical Blackhawk breccia on the top of Blackhawk Mountain indicates that the breccias comprising Blackhawk Mountain are both depositional and tectonic in origin and that they are indistinguishable. For these reasons they are not separated but rather grouped with the Furnace formation, undifferentiated.

A moderate sized landslide is found on the ridge north of Chicopee Canyon in the quartzites of the Chicopee formation. This feature is being much more rapidly eroded from the north than the south due to the steeper gradients of the streams on the north side.

Streams. The ridge west of the Helendale fault is breached by only one intermittent stream, the one that follows the fault in Cushenbury Canyon and cuts through the ridge at Chicopee Canyon. In Chicopee Canyon the gradient of the stream is about 600 feet per mile. The gradient is less in Cushenbury Canyon but in the intermediate zone between the two canyons, west of BM 5783, the stream drops at the rate of 1200 feet per mile for a distance of a quarter of a mile. This steep gradient may be attributed to two factors: the deflection of the stream's course from the Helendale fault zone to the higher standing west block, and the less resistant nature of the granitic rocks through which the stream flows at this point.

From the mouth of Chicopee Canyon to the south border of the area, all streams lose their identity when they cross the Helendale fault and flow out on the flat. For all practical purposes the Cactus Flat-Smarts Ranch area may be considered a temporary base level for the intermittent streams flowing east from the Johnston Grade ridge. Streams are cutting across the flat area from the east in the vicinity of Cactus Flat, the Johnston Grade, and near Smarts Ranch.

Structural Control on Topography. The Helendale fault has had a profound effect on the topography of the region north and east of Baldwin Lake. The higher-standing west block is being dissected by many small intermittent streams flowing at right angles to the fault. Deposition occurs on the flat east of the fault. Cushenbury Canyon has been eroded by a stream following the Helendale fault zone.

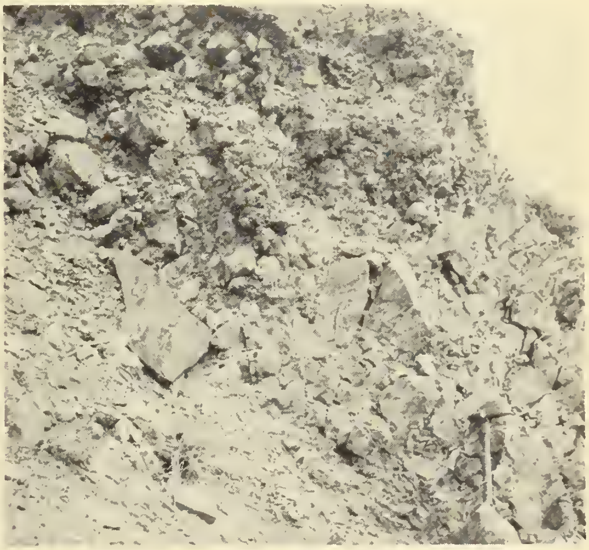

Figure 19. Helendale fault zone. Fractured Furnace limestone north of Johnston Grade.

The traces of the Doble, Chicopee Canyon, and Blackhawk Mountain faults are characterized by small valleys which result from the removal of the material whose resistance to erosion has been lessened by fracturing.

Lithological Control on Topography. The low resistance to erosion of the Cactus intrusive rocks has been mentioned previously. This lithologic control on topography is clearly shown on the Johnston Grade where the most extensive erosion of the ridge west of the Helendale fault coincides with the cropping out of granitic rocks. The quartz monzonite of Burnt Flat is being eroded from the east on a wide front rather than in one or two well-developed canyons as is typical of the marble.

The effect of structure and lithology on the topography of Blackhawk Mountain has been noted above. Over the rest of the area the marble gives rise to fairly sharp but smooth ridges. Only the massive beds of the white member of the Furnace limestone form cliffs. East of the Johnston Grade the marble forms smooth slopes upon weathering.

The white quartzites of the Chicopee formation and Saragossa quartzite form cliffs. The area west of Baldwin Lake and the crest of the ridge between Cactus Flat and Baldwin Lake are excellent examples. The cross-laminated quartzites of the Chicopee formation, although not as resistant as the white quartzite, form cliffs more readily than the rocks of the Furnace limestone and Cactus intrusives.

The major part of the Baldwin gneiss weathers quite easily and forms rolling topography. The coarser-grained augen gneiss and the igneous dikes are more resistant than the finer-grained gneiss and they stand out as slight ridges. The pegmatites in the granitic gneiss also cause minor irregularities in the topography due to their being more resistant than the country rock.

ECONOMIC GEOLOGY

Metallic Minerals

Prospecting for gold in the Johnston Grade area dates from 1860 when the Holcomb Valley placer deposits were discovered. The majority of the exploration work has centered on the many iron-rich fracture zones in the quartzites of the Saragossa and Chicopee formations. The most famous mine in the area is the Doble mine, or Gold Mountain mine as it was called before 1900 when E. S. "Lucky" Baldwin was the owner.

Doble Mine. The Doble mine is in a highly faulted and fractured thrust sheet of massive white quartzite belonging to the Saragossa quartzite. The gold is disseminated in the fractured quartzite, in cavities associated with iron, and in galena veins. Fred Tomlinson who first worked in the mine about 1910 states that in the earliest operations provision was made to concentrate the galena and remove the gold by smelting. From slightly before 1910, however, the ore has been crushed only and the free gold extracted. The value of the gold taken from the mine is not recorded.

Miscellaneous. Numerous prospects on Blackhawk Mountain have uncovered small galena veins which in places contain minor amounts of gold. The red-stained fracture zones also contain disseminated gold. The mines of Blackhawk Mountain were first mentioned in the Ca fornia State Mineralogist's Report for 1889.

Minor amounts of gold, silver, lead, and zinc have be recovered from the sulfide and carbonate contact zone the Mohawk mine.

In the roof pendant area east of the Johnston Gra small quantities of molybdenite and scheelite are found the skarn zone developed between the marbles and grani intrusives.

Non-Metallic Minerals

Pure white marble is occasionally quarried in Cush bury Canyon. Crushed and sacked, it is sold for use in t refining of sugar.

East of the Johnston Grade a small crusher has be set up and marble cropping out there is quarried, crush and sacked. It is then trucked to Los Angeles and s as roofing granules.

Small quantities of iron-stained quartzite are quarr from talus slopes on Gold Mountain and sold as decorat building stone. Some of the thin-bedded white quartz is suitable for use as flagstone.

GEOLOGIC HISTORY

The geologic record in the Johnston Grade area ope with the deposition of the Baldwin sediments. This w followed by the metamorphism and intrusion of the se ments by pegmatitic granitic rocks and later granitic d rocks. Although these events can only be dated as p Mississippian, the Baldwin gneiss is believed to be p Cambrian because of its complex evolution.

The next event appears to have been the deposition the massive white sandstones of the Saragossa quartzi Its age cannot be determined because it is here expos only in a thrust plate. However, it is believed to be p Mississippian and younger than the Baldwin gneiss cause of the absence of intrusives in it. The quartz, t feldspathic, and the cross-laminated sandstones of t Chicopee formation were deposited on the eroded surf of the Baldwin gneiss in late Devonian to early Carb iferous time. The Furnace limestone was conformal deposited on the Chicopee formation during the C boniferous.

Following the deposition of the Furnace limestone a before the intrusion of the Cactus granitics in the Ju Cretaceous, the rocks of the Johnston Grade area w subjected to intense folding and faulting. The formati of the overturned anticline in Chicopee Canyon was companied by shearing and metamorphism of the Chi pee and Furnace sediments to quartzite and marble.

Movement on the Doble fault, Chicopee Canyon fau and the faults west of Whisky Springs also took pl prior to the intrusion of the Cactus quartz monzonite. T age of the Saragossa thrust can only be dated as p Doble faulting.

During the Jura-Cretaceous, the Paleozoic and p Cambrian rocks of the Johnston Grade area were truded by the aplite, quartz diorite, and quartz monzon facies of the Cactus quartz monzonite. Poorly develop contact zones were formed in the Furnace limestone the intruding granitics.

Following a long period of erosion, reverse faulting Blackhawk Mountain occurred during the late Cenoz

Geologic history

Age	Formation	Folding and faulting	Igneous activity	Result
Quaternary	Alluvium			Deposition of alluvium east of the Johnston Grade and in the Baldwin Lake basin.
Quaternary		Faulting		Helendale vertical fault system.
Quaternary	Fanglomerate			Deposition of quartzitic fanglomerate on Cactus Flat and southwest of Doble.
Late Cenozoic		Faulting		Reverse faulting and brecciation of Blackhawk Mountain.
Erosion				
Jura-Cretaceous			Yes	Intrusion of Cactus quartz monzonite. Thin contact zones.
		Folding and faulting		Overturning, high-angle and thrust faulting of older rocks. Shearing and metamorphism of Paleozoic sediments.
Carboniferous (?)	Furnace			Deposition of over 7,000 feet of limestone, shaly at base.
Devonian-Carboniferous (?)	Chicopee			Deposition of 1,150 feet of sandstones and micaceous sandstones. Some basal limestone.
Pre-Carboniferous (?)	Saragossa			Deposition of over 1,000 feet of high-quartz and feldspathic sandstones.
Erosion				
Pre-Cambrian (?)	Baldwin gneiss	Folding	Yes	Deposition and metamorphism of Baldwin sediments. intrusion of pegmatitic granitics and later dike rocks.

Fanglomerates were deposited southwest of Cactus Flat and west of Baldwin Lake during the quaternary. The Helendale fault cuts the fanglomerate between Cactus Flat and the Johnston Grade. Alluvium is now being deposited east of the Johnston Grade and in the Baldwin Lake basin.

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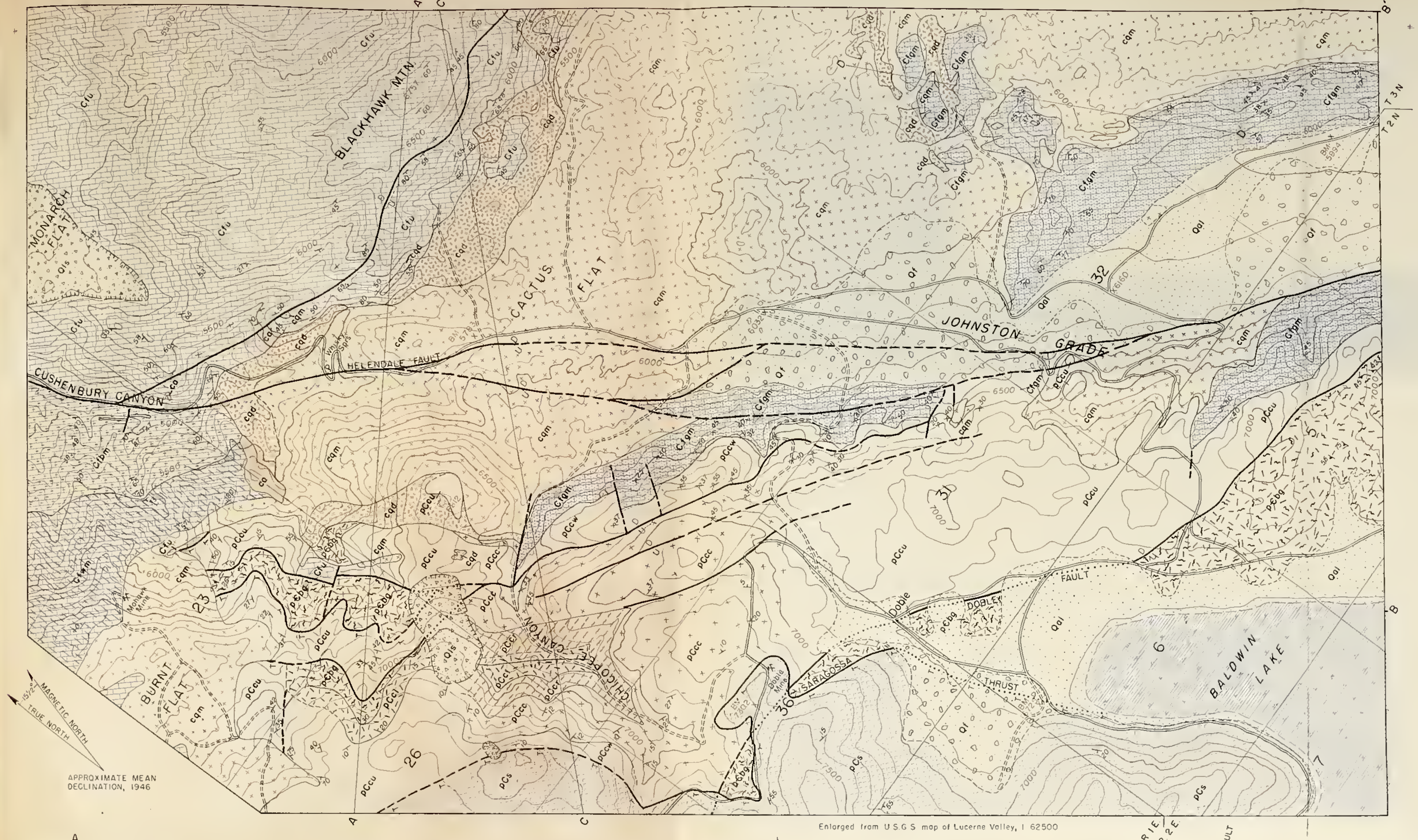
OLAF P. JENKINS, CHIEF

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES

SPECIAL REPORT 31
PLATE 1



Enlarged from U.S.G.S. map of Lucerne Valley, 1:62500

EXPLANATION

SEDIMENTARY ROCKS

CENOZOIC — QUATERNARY
- Qls Landslides
- Qal Alluvium
- Qf Fanglomerate

UNCONFORMITY

PALEOZOIC — MISSISSIPPIAN-PENNSYLVANIAN(?) — Furnace limestone
- Cfbm Black member; thin bedded dark gray marble
- Cfwm White member; white and light gray massive marble
- Cfgm Gray marble member
- Cfu Undifferentiated

PRE-CARBONIFEROUS (?) — Chicopee formation
- pCcw Upper member; white quartzite
- pCcc Cross-laminated quartzite member
- pCcr Ripple marked quartzite member
- pCcl Lime silicate and quartzite member
- pCcu Undifferentiated
- pCs Saragossa quartzite; massive white to buff quartzite

UNCONFORMITY

PRE-CAMBRIAN(?)
- p€bg Baldwin gneiss, granitic gneiss, augen gneiss and schist

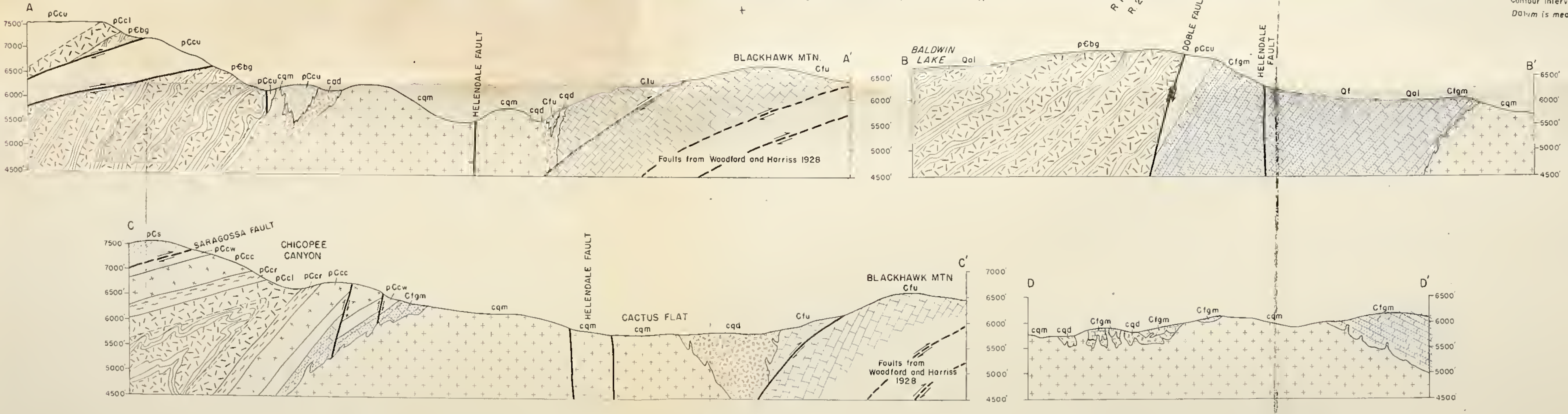
IGNEOUS ROCKS

MESOZOIC — JURA-CRETACEOUS
- cqm Quartz monzonite
- cqd Quartz diorite
- ca Aplite

- Contact, dashed where approximate
- Fault, dashed where approximate
- Thrust fault
- Concealed fault
- Overturned anticline
- Strike and dip of beds
- Strike and dip of overturned beds
- Strike of vertical beds
- Strike and dip of foliation
- Mine

1000 500 0 1000 2000 3000 4000 5000 FEET
1 MILE

Contour interval 100 feet
Datum is mean sea level



GEOLOGIC MAP AND SECTIONS OF THE JOHNSTON GRADE AREA, SAN BERNARDINO MOUNTAINS, CALIFORNIA

Geology by Robert Guillou 1950-51